## Introduction

The role of carbon (C) is significant in the climate change perspective. Because of the large quantity of C stored in soils (81% of the world's terrestrial carbon), small modifications in soil C status may have prominent effect on the global carbon balance and hence on climate change. It is therefore important to understand the dynamics of soil carbon as well as its role in terrestrial ecosystem carbon balance and the global carbon cycle. Multiple land uses especially agriculture land, forestland, grassland, and wetland act as source and sink of carbon. Soil carbon sequestration potential of different land uses varies on spatial and temporal basis along with the interplay of environmental factors, land use changes and management practices. Hence it is necessary to embark upon regional level studies to understand the soil carbon status of the area and its regional contribution to global warming potential so as to formulate a management plan emphasizing climate mitigation measures. It may be noted that the source of the major bulk of the soil carbon is contributed by the organic carbon (84 to 97%) and hence the present study is focused on the organic carbon and dynamics in relation to climate change.

## Objective of the study

### General objective

To study the soil carbon dynamics of selected multiple land use categories of Kottayam district from a climate change perspective.

### Specific objectives

- To study the baseline soil carbon, its stock change variations and source/sink status in the study area
- To determine the soil carbon dynamics of a selected soil series under multiple land use categories

- To address the impacts of selected emerging monoculture plantations on soil carbon pool and its dynamics
- To identify and assess the changes in soil carbon pool of a selected grassland due to the land use conversions and disturbances
- To identify the current carbon pool status of a selected forest region
- To study the role of land use and land use change on the fluvial carbon and its speciation of a selected water shed region
- To study the role and importance of Earthworm and Vetiver plant as biological tool in the management of soil carbon sequestration

## Methodology

### Study area

The study area is Kottayam district, which is positioned a little south to central Kerala in India and lies between $9^{o}$ 23'- $9^{o}$ 52' N latitude and $76^{o}$ 21'-77 $^{o}$ E longitude and is bounded on the north by Ernakulam district, west by Alapuzha district, and the Vembanad Lake forms the western boundary. It sprawls over a total area of 2208 sq km. The study transect covers different land use falling under the multiple land use categories prescribed by IPCC for carbon inventory. The region is endowed with plantations, cropland, grasslands, forest, paddy fields, etc. Along the study area marked variations can be tracked in topography, hydrogeology, climate and edapic characters, land use pattern, land use management practices etc. The major physiographic units identified in this district are lowland, midland, mid-upland, uplands and highlands. The study transect comes under a humid tropical climatic regime with severe summer and plentiful rainfall during monsoons. According to Bench Mark Soils of Kerala (2007), there are five major soil series in the study area which varies significantly in its characteristics.

## Methods

Measurement methods for assessing loss or accumulation of soil carbon were done as per the methods prescribed by IPCC (2006). In order to implement the method on a regional level, the guidelines for Land Use Land Use Change and Forestry (LULUCF) was down scaled to suit a plot level analysis of the desired Carbon pools. Soil samples were collected from the study area suitably to fulfil the objectives of the case studies. The collected samples were air dried, powdered and treated properly for further analysis using standard methodologies and protocols. Experimental pot studies using earthworm and vetiver were also carried out to demonstrate the management options for soil carbon sequestration. The various parameters studied include Soil Organic Carbon (SOC), Particulate Organic Carbon (POC), Carbon mineralisation ($C_{min}$), Carbon functional groups, Organic carbon fractions like Carbon labile (CL) and Carbon non labile (CNL) or recalcitrant, Water stable Aggregates (WSA), Global Warming Potential (GWP) of soil emissions etc.

## Studies and findings

The study consists of a general baseline investigation on soil carbon dynamics of different land use categories through specific studies. The study revealed the influence of land use categories and soil series combinations with various characteristics on soil carbon dynamics. The soil series based on their characteristics varies and the choice of optimal land use category in order to support maximum soil organic carbon (SOC) pool fluctuates accordingly. The study throws light on the current land use and land use change scenarios, impacting on the net soil carbon sequestration and loss, emphasising the importance of decision making and appropriate land use management strategies for making soil a better C sink rather than source by assigning suitable land use to each soil types.

In order to portray the role of land use change and soil management on soil carbon dynamics five different case studies have been carried out. ***The first case study*** dealt with

the soil carbon dynamics and global warming potential of selected soil series which explored the role of land use as a determinant of the soil's ability to sequester and store carbon. This data summary provides an understanding on the rates of SOC sequestration potential of 3rd soil series (Kottappuram series) under various land use categories and indicates the relative importance of the combination of specific soil type or series and land use as a functional system that influence the rates of organic carbon sequestration in soil. The study revealed the significance of mixed land use as optimal land use category for this particular soil series in terms of soil carbon dynamics indicators from a climate change perspective.

***The second case study*** was on the effect of monoculture plantation on soil carbon storage. The study revealed the implication of emergence of monoculture plantation on soil carbon storage and sequestration processes. The spread of monoculture plantation especially that of rubber plantation as a major land use in the study area is of due importance. The overall observation of various parameters suggests that monoculture plantation especially that of rubber monoculture practices is detrimental from a soil carbon sequestration view point. Hence the present study showcases the implications of monoculture plantation on the soil's innate capacity to act as a source or sink of C and its further contribution to climate change. The work also calls for an attention regarding the selection of an optimal land use pattern for the study region.

As an environmental feedback to climate change, the soil carbon alterations of selected forest system has been dealt in detail in ***the third case study***. Forest ecosystems are potential sites of Carbon sink and source depending on the integrity of the system and understanding forest disturbances and their impacts is critical for a better quantification of regional carbon stocks and fluxes. This case study shows that disturbances greatly alter the carbon cycle at various spatial scales. The SOC storage capacity or the sink capacity of various forest sites can be significantly altered by the extend of disturbance. The study highlights the potential of selected indicators in portraying the impact of disturbances on soil carbon accruals and carbon alterations in the forest ecosystem which act as an

environmental feed back to climate change. Thus understanding forest land and soil based disturbances towards regional carbon dynamics is critical in decision making since forestlands are abodes of terrestrial C accruals.

***The fourth case study*** discusses the effect of land use conversion on the soil carbon storage of a grassland region. Quantifying the response of soil C is essential for understanding the nature and extent of grassland system's response to global warming as a major land use category. The study shows that the region is vulnerable to degradation due to exacerbated intensive soil use and land disturbance as a result of human interference affecting its natural equilibrium. Apart from native grassland sites, the conventional cropping site of Cardamom is also found to offer innate capacity to store soil carbon at a considerable rate. An understanding on the effect of land use conversion and disturbance intensity in soil carbon storage is therefore needed in the sustainable management of grasslands.

***The fifth case study*** illustrates the spatial variation in fluvial carbon speciation and transport under land use change. Processes like terrestrial sedimentation or accumulation and riverine transport represents the missing link of soil C which should be taken into consideration while discussing the regional soil C dynamics. The present study illustrates the influence of land use and land use change in a watershed region and its impact on the riverine carbon transport.

The role of land based-biomass oriented and soil based earthworm facilitated C sequestration has due significance in mitigating current climate change issues by locking up significant amounts of C from escaping to atmosphere. Hence in order to portray the importance and scope of land and soil based natural way of improved C sequestration, ***experimental pot studies*** have been taken up. ***The first study*** dealt with the role and importance of Earthworm as a biological tool in soil carbon sequestration. The study explains the role and effect of two earthworm species in soil carbon dynamics and sequestration of an agro ecosystem. The findings indicate the potential of earthworms to

enhance soil C and nutrient dynamics with implications for long-term sustainability and greenhouse gas mitigation in agricultural systems. Results also suggest that earthworms may provide more benefits to organic agricultural systems, which utilize large quantities of C-based amendments, than to conventional systems that rely heavily on mineral fertilizers and have low inputs of C. The study has yielded valuable information to assist in developing responsible agricultural management strategies from a more sustainable and climate change perspective. The potential of vetiver plant in soil carbon sequestration was taken up as ***the second experimental study***. The study revealed that the vetiver grasses could dramatically enhance general soil status by improving soil quality, as well as sequestration of carbon. The studies taken up have thus generated information on the role of land use and land use changes and soil types in soil carbon dynamics.